# Using the Special Sensor Microwave Imager to Monitor Land Surface Temperatures, Wetness, and Snow Cover

**(The temperature product is still experimental)**

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The products presented on the National climatic Data Center (NCDC) web page include full and anomaly fields for land surface temperature, wetness, and snow cover (peer reviewed references are provided below). These climate products are derived from the Special Sensor Microwave Imager (SSMI), a polar orbiting satellite with global coverage. The fields are presented as both global and higher resolution North American images. The data are available in near real time by the fifth day of the following month. Anomalies are derived from the 1992-1997 base period (base period includes 1998 when it is available). The spatial resolution is $1^0$ for all three products. The '*experimental*' temperature period is not available when snow cover is observed over a grid box during a portion of the month. Furthermore, temperature anomalies are not available, if the climatology places snow cover in a grid during 3 months of the base period. Under these conditions the observed snow cover represents the area where temperature anomalies are not available during that month. The wetness products represents the percentage of the radiating surface that is liquid water. Since this spectrum of microwave radiation can penetrate vegetation, the radiating surface can be vegetation and/or the ground. Liquid water can originate from recent rainfall, melting snow, ponding and/or flowing surface water, and/or irrigated fields. Surface water does necessary equate to soil moisture, since the signal does not penetrate any appreciable depth below the surface. Ignore the wetness and snow cover anomalies over Glacial ice (Greenland and Antarctica), since the microwave emission originating deep within the ice pack can product some unique (false) signatures. All three of the above climate products have been developed by the National Environmental Satellite and Data Information Service (NESDIS) at two cooperative centers NCDC and Office of research and Application (ORA).

Satellite measurements offer a possible way to fill in the data voids and obtain a complete map of surface temperature, surface wetness and snow cover over the entire globe. To accomplish this, we identify numerous surface types and make dynamic adjustments for variations in emissivity. Training data sets were used to define the relationship between the seven SSM/I channels and the near surface temperature. For instance, liquid water on the surface reduces emissivity; therefore we developed an adjustment to correct for this reduction. Other surface types (e.g., snow, ice, and deserts) as well as precipitation are identified, and numerous adjustments and/or filters were developed. The Global and U.S. networks of first order and cooperative stations, quality controlled by NCDC, serve as validation.

The surface water depresses the emissivity and therefore dynamic adjustments are necessary to derive the correct surface temperatures, and this emissivity reduction provides the signal for the surface wetness index. Multiply frequencies available on the SSMI instrument have different responses to the liquid water on the land, and this response across the microwave spectrum indicates the percentage of the ‘radiating surface’ that is water. Once this percentage is known, we can use the emissivity of water and dry ground to make the correction for the actual surface temperature. The snow cover product identifies the frequency of snow observed on the surface, and it is presented as a monthly percentage. This product relies on the fact that snow reflects high frequencies more than low frequency, known as a scattering signature. Therefore when a scattering signature is observed and false ones removed, the satellite observes the global distribution these derived products as it continues to rotate between the poles 14 times each day.

**Model used to derive the wetness index and land surface temperature**

The SSM/I brightness temperatures, $T_B$ , are highly correlated with surface emissivity, $\epsilon_s$ , and surface temperature[1], i.e., $T_B(\nu) = \epsilon_s(\nu)T_s + \Upsilon_v[1- \epsilon_s( \nu)]V$. Two different techniques exist for deriving surface temperature. A “split window” technique uses dual frequency measurements around the 22 GHz water vapor line to eliminate the emissivity variable and uses a statistical relationship between surface temperature and water vapor, V, to derive temperature[1]. The second approach is summarized below and uses multiple channels (19, 37, 85 GHz) to retrieve surface temperature by correcting the measurements for emissivity[2].

**Multi-channel Algorithm:** For *snow-free* surfaces, the emissivity varies predominately due to changes in surface wetness and vegetation cover. The smallest variation in emissivity is obtained using the vertically polarized - highest frequency channel at 85 GHz ( $_1$). The lower frequency channels at 19 GHz ( $_2$) and 37 GHz ( $_3$) are used to correct the 85 GHz measurement due to surface wetness. These considerations are used to derive surface temperature, viz.,

$$(1) \quad T_B(\nu_1) \approx \epsilon_s( \nu_1)T_s$$

where

$$(2) \quad \epsilon_s(\nu_1) = \epsilon_o - \delta\epsilon \, .$$

Equation (2) contains the emissivity of dry vegetated surfaces ( $\epsilon_o \approx .95$) and the emissivity correction, $\delta\epsilon$. The emissivity correction is

$$(3) \quad \delta\epsilon = f \, ( \epsilon_o - \epsilon_w)$$

which depends on the fractional area, f , of wet surfaces within the SSM/I footprint and the emissivity of wet land , $\epsilon_w$. The correction depends on the slope of emissivity with frequency,

$$4) \quad \delta\epsilon \approx \alpha[\epsilon_s(\nu_2) - \epsilon_s( \nu_1)] + \beta[\epsilon_s( \nu_3) - \epsilon_s( \nu_2)] \, .$$

Combining (1), (2) and (4) we obtain an equation for surface temperature;

$$T_s \approx \frac{T_B(n_1)}{e_s(n_1)} = \frac{1}{e_o}\left[T_B(n_1) + W\right] \tag{5}$$

where

$$W = a\left[T_B(n_2) - T_B(n_1)\right] + b\left[T_B(n_3) - T_B(n_2)\right] \tag{6}$$

Equation (5) contains the brightness temperature correction due to surface wetness in the form of a wetness index, i.e., $W = \delta\epsilon\, T_s$. The and parameters in (6) are determined empirically using coincident SSM/I measurements and actual surface temperature observations.

## REFERENCES


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